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Semistructural Allografting in Bone Defects After Curettage

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Background and Objectives: A variety of aggressive benign bone tumors often require wide bone and soft tissue excision for adequate local control, but this creates a large defect and a seriously weakened extremity. Restoration of limb function presents a difficult problem.
Methods: The treatment of 104 patients with space occupying lesions of the long bone were analyzed. Deep-frozen (−70°C) cortical strut allografts with or without allogeneic cancellous bone graft were implanted into the defects after extensive intralesional curettage. Thirty-six patients had fibrous dysplasias, 29 unicameral bone cysts, 22 giant cell tumors, 12 aneurysmal bone cysts, 3 benign fibrous histiocytomas, and 2 ossifying fibromas. Fifty-six patients had pathologic fracture. The average volume after curettage was 210 ml (range 60–460 ml). The average follow-up period was 50 months.
Results: At follow-up evaluation, the radiographs demonstrated complete incorporation of the allogeneic implant and new bone formation in the cavity in 83% of the patients (86/104). All fractures healed. There was no local recurrence or fracture of the cortical graft; neither were there other serious complications except one avascular necrosis of the femoral head. Good or excellent functional results were found in 97% (101/104) of the patients.
Conclusions: For large osseous defects, the reconstructive technique using cortical stent allograft provides increased strength, easy fixation, remodeling of the cystic defect, and healing of the fracture and prevents deformity. However, remodeling occurs slowly and may never be complete. *J. Surg. Oncol. 1998;68:159–165.* © 1998 Wiley-Liss, Inc.

KEY WORDS: bone; tumors; curettage; allograft

INTRODUCTION

The goal of treatment of large space-occupying benign lesions in bone is the removal of the lesion and restoring the structural integrity of the bone. Central defects are potentially the simplest to repair. The rim of the cortex is intact circumferentially and can be used to provide mechanical stability to the long bone, making the central defect in the long bone a contained cavity, which is protected from direct mechanical loading. In such a case structural grafting is not necessary. Semistructural stent grafting, hardware, or use of a fixation device are often used after wide decortication or windowing. The autogenous bone graft, which may be vascularized or nonvascularized, has been considered the best method for restoration of these defects [1,2]. However, sufficient quantities of autogenous graft for a huge cavity may be impossible to obtain; and, cancellous bone cannot be used to replace extensive bone defects because of its lack of mechanical strength. As an alternative, bone substitutes have been widely used, but their biocompatibility is low [3–5].

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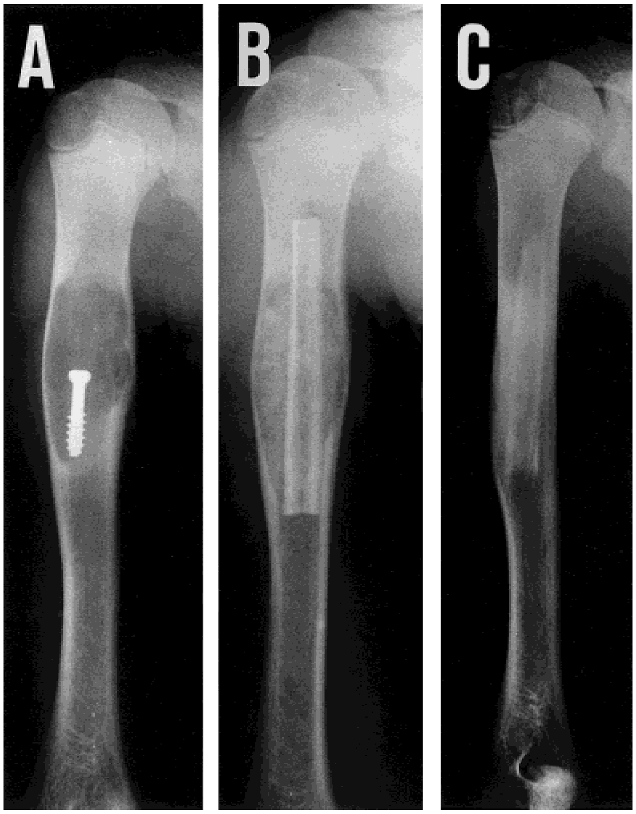

Fig. 1. This 13-year-old boy with soreness of the right upper arm had a history of bone cyst of the humerus and had received corticosteroid injection therapy and cannulated screw surgery for the lesion at 8 years of age. **A:** Radiograph showing recurrent expansile bone cyst over the humerus with a thin cortex and screw in canal. **B,C:** Healing of the cyst and good bony incorporation of the strut graft at 3 months and 2.5 years postoperatively.

In view of these problems, allogeneic segmental cortical strut grafts may be useful in the treatment of cavitary lesions. It not only serves a space-filling function but also provides an immediate mechanical strength in lesion sites. This paper presents the clinical results of allogeneic cortical strut grafting in patients with removal of a large cavitary long bone lesion.

MATERIALS AND METHODS

From 1987 to 1994, a total of 195 patients with cystic bone lesions were treated with curettage and allografting. Among them, 104 patients with large bone defect secondary to tumor removal received allogeneic cortical strut (deep-frozen −70°C) composite bone grafts. There were 57 men and 47 women, aged 11–60 (average 26) years. Forty-two patients had lesions located at the proximal femur; 21 at the humerus shaft (Fig. 1), 14 at the distal femur (Fig. 2), 10 at the proximal tibia, 7 at the tibia shaft (Fig. 3), 6 at the proximal humerus, and 4 at the femur shaft (Table I). Thirty-six patients had fibrous dysplasia, 29 simple bone cysts, 22 giant cell tumors, 12 aneurysmal bone cysts, 3 benign fibrous histiocytomas, and 2 ossifying fibromas (Table II). Sixty-one patients were classified as having aggressive lesions and 43 patients as having active lesions.

The relative indications for surgery were failure of operative or nonoperative treatment, pathologic fracture, progressive deformity, progressive expansion, or cortical destruction from the lesion with impending or actual fractures. The absolute indications were that all lesions had a volume larger than 60 ml and longer than 6 cm as well as thin cortex. Fifty-six patients had pathologic fractures and 26 had recurrent lesions after treatment elsewhere. Enneking's surgical staging system was used to evaluate and compare the results of treatment. Surgical stage 1 or latent lesions were confined intraosseous lesions; the active stage 2 lesion had progressive bulging of the cortex with further encroachment on the subchondral bone plate but were still intraosseous; the aggressive stage 3 had a lesion extending extraosseously with an associated soft tissue mass.

All patients were operated on by one of the authors (H.N.S.), and all lesions were treated with modified intralesional curettage through a wide cortical window to permit visual access to the entire lesion, as well as extensive removal of bone and tumors. The modified intralesional curettage included wide excision of the extraosseous extension. This method was described in the Mayo Clinic report that emphasized the need for complete exteriorization and meticulous extension of the curettage with use of power instruments [6]. A high-speed burr was utilized to facilitate tumor removal and a pulsatile lavage irrigation was used in the cavity. The average volume after tumor removal was 60–460 ml (average 210 ml).

After the tumor had been removed, the reconstructive procedures were mainly allogeneic cortical bone strut grafting. The allogeneic cortical bone was prepared from bone bank tissue, deep frozen at −70°C [7,8]. The grafts were segmental cylinder cortical struts, from radius, ulna, fibula or clavicle, and were used singly or in multiples. Occasionally, humeral shaft and proximal metaphyseal cancellous bones were applied to position the cavity lesion. Forty-two patients had multiple segments of allogeneic cortical bone implanted after intralesional removal of the tumor. Single or multiple stent strut grafts were used, depending on the defect and the size of the strut. For 14 patients in whom giant cell tumor of bone extended up to the articular surface of the knee joint, an autogenous bone graft was placed and impacted beneath the articular surface so as to restore the articular congruity. An allogeneic strut containing metaphyseal cancellous bone was positioned within the canal and impacted to support the subchondral autogeneous bone graft. The remaining defect was filled with allogeneic cancellous bone chips. An internal fixation device was used, de-

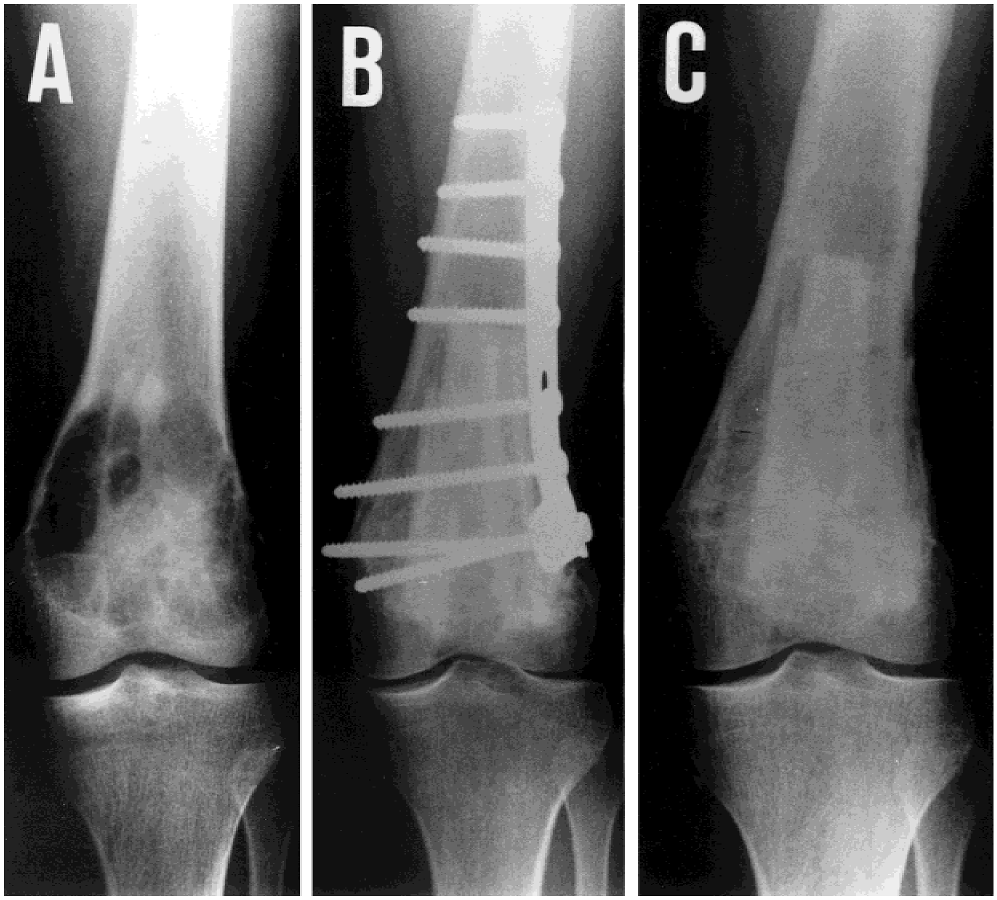

Fig. 2. Giant cell tumor in the condyle of the femur of an 18-year-old woman. **A:** The metaphyseal pathologic fracture was associated with bony destruction. **B,C:** Reconstruction with allograft and plate was performed at 1 and 3 years postoperatively.

pending on the location and bony framework. A strut graft was used alone without fixation in 27 patients.

A rigid internal fixation was applied in conjunction with the strut graft in 62 patients who were active and had pathologic fractures or lesions of the lower extremities. Prophylactic internal fixation to prevent the occurrence of pathologic fracture was made for tumor deposits in the femoral area involving any amount of cortex. There was no need for internal fixation over tibial and humeral lesions. Limited internal fixation for the strut graft sliding was used in 15 patients who had adequate bone structure in the humeral area. No cast or brace was required. The patients were then allowed to exercise and ambulate with partial weight-bearing during the initial postoperative period and with full weight-bearing after 6 weeks. They might return to normal activities and had a good function of limbs at 3 months after surgery. The hardware was removed 3 years postoperatively.

Adjuvant treatment using chemical cauterization with phenol and alcohol was applied in association with an intralesional excision of fibrous dysplasia, aneurysmal bone cyst, and giant cell tumor.

At follow-up evaluation, radiographic evaluation and functional score were used to assess the outcome. Plain radiographs including anteroposterior and lateral views were obtained immediately after surgery and at 3-month intervals thereafter for each patient. With the first operative radiograph used as the baseline, each successive radiograph was examined for evidence of bone healing. All radiographs were independently reviewed by the authors, and any differences in grading were resolved by repeated review of the radiographs. Evaluations at 2 year follow-up were based on remodeling of the lesion and bone incorporation. Each of the radiographs was studied for trabeculae, bone density, border of the cortical graft, border of the cavity, internal callus formation, and subchondral region for assessment of incorporation of the bone graft. Each of these variables was graded on an arbitrary scale, with values ranging from 1 to 3 (Table III). Analysis of the final bone incorporation was performed by the authors. The grades were defined as follows: (1) evident incorporation (score 16–18); (2) delayed incorporation (score 13–15); (3) sclerosis of the graft (score 10–13); and (4) no incorporation (score ≤9) (Table IV). The functional results were evaluated with the Musculoskeletal Tumor Society's rating score of limb salvage [9].

Fig. 3. Polyostotic form of fibrous dysplasia of tibia. **A:** Radiographs show two centrally expanding lesions with involvement jeopardized the integrity of the shaft. **B:** The lesion was treated by subtotal excision curettage and was replaced with a long cortical strut and cancellous grafts. **C:** Healed cyst at 2 years postoperatively.

TABLE I. Location of Benign Cystic Tumors

Bone	Location	No. of lesions
Humerus	Proximal	6
	Shaft	21
Femur	Proximal	42
	Shaft	4
	Distal	14
Tibia	Proximal	10
	Shaft	7
		104

Seven primary factors considered include (1) motion, (2) pain, (3) stability, (4) deformity, (5) strength, (6) functional activity, and (7) emotional acceptance. Each of these primary factors was rated as excellent, good, fair, or poor. In the excellent category, 6 of 7 primary factors must rate excellent. The seventh may be good, fair, or poor. In the good rating, 6 of 7 primary factors must rate good or better. The seventh may rate fair or poor. For a rating of fair, 6 of 7 primary factors must rate fair or better, and seventh may rate poor. In a poor rating, 2 or more of the primary factors must rate poor.

TABLE II. Pathologic Diagnosis of Cystic Tumor

Diagnosis	No. of patients
Fibrous dysplasia	36
Simple bone cyst	29
Giant cell tumor	22
Aneurysmal bone cyst	12
Benign fibrous histiocytoma	3
Ossifying fibroma	2
	104

TABLE III. Radiographic Evaluation of Bone Incorporation*

Parameter	Score	Description
Trabeculae	1	Absent
	2	Sclerosis
	3	Present
Bone density	1	Postoperatively
	2	Increased
	3	Normal
Border of the cortical graft	1	Clear
	2	Vague
	3	Absent
Border of the cavity (host–donor junction)	1	Clear
	2	Vague
	3	Absent
Internal callus or new bone formation	1	Minimal
	2	Mild
	3	Active strong
Subchondral region	1	Sclerosis
	2	Increased density
	3	Clear trabeculae

*Radiographic evaluation was performed at 3-month intervals.

TABLE IV. Assessment Grade of the Bone Graft Incorporation

Bone incorporation	Score
Evident incorporation	16–18
Delayed incorporation	13–15
Sclerosis of the graft	10–12
No incorporation	≤9

RESULTS

The average postoperative follow-up period was 2–6 years (average 50 months). Three patients had postoperative superficial wound infection and recovered after conservative treatment with antibiotics. All bone grafts showed progressive remodeling and incorporation. The average bone graft incorporation score in 104 patients was 15.1 (range 11–17) at 2 years postoperatively. The average incorporation score in 82 patients was 15.5 (range 11–18) at 3 years postoperatively. At last follow-

up, radiographic evaluation revealed a clear incorporation of the allograft in 86 patients, delayed incorporation in 12 patients, sclerosis of the graft in 6 patients. The average bone graft incorporation score was 16.3 (range 11–18).

There were no fractures of the cortical graft or metallic implant at 50 months follow-up. All patients exhibited complete healing of the pathologic fracture. There were no instances of allograft infection, and surprisingly, no local recurrence (or further recurrence for recurrent patients after secondary operations). No patients developed lung metastasis during the 3-year follow-up period. There were no deleterious effects on the articular cartilage after the exteriorization and curettage of lesions, as frequently occurs in giant cell tumor patients who receive bone grafts. The surgery did not interfere with joint function and the overall functional results were good in 53 and excellent in 48 patients. Two patients had fair and one patient had poor results. All the patients, except three were able to return to normal activities and had good limb function at 3 months postoperatively.

One patient received reduction and internal fixation for a bone cyst lesion and pathologic fracture of the femoral neck elsewhere. However, the femoral neck was collapsing progressively without fracture healing. Reoperation was carried out with curettage, allogeneic cortical strut support, and dynamic hip screw and plate fixation. At follow-up, the cystic lesion and pathologic fracture were healed. Four years postoperatively, the patient developed avascular necrosis of the femoral head which was not involved in the previous surgery. The final functional result was poor. Another patient received femoral condyle surgery for a giant cell tumor lesion. He had developed traumatic fracture of the ipsilateral tibial plateau one year after tumor surgery. Open reduction and internal fixation of the tibial plateau were performed. The femoral condyle lesion and tibial plateau fracture were completely healed and the implant was removed 3 years later. However, the functional outcome after the fracture and surgery was fair. A third patient had a neglected pathologic fracture of the femoral neck caused by a giant cell tumor of the proximal femur preoperatively. The patient received surgery for internal fixation elsewhere and the fixation later refractured. Reoperation was carried out for extensive curettage and allografting as well as dynamic hip screw and plate fixation. Unfortunately, the femoral neck had a slight collapse and the union resulted in a fair functional outcome.

DISCUSSION

Large contained defects after tumor curettage are difficult to manage. Many modalities of treatment have been tried but none provide comprehensive treatment with highly satisfactory results [10–13]. Common treatments include palliative, internal fixation device, and curettage with or without bone graft. Various reconstructive options could be considered for filling the curettage bone defect. If the defect after curettage is not extensive, it might be more reasonable to restore the anatomy by simply using an autograft or letting it be [14]. The period of healing could be short enough that prolonged cast immobilization would not be necessary. Extensive defects that would carry a high risk of postoperative fracture and collapse or require long periods of cast immobilization are probably better reconstructed with graft. In general, autogenous cancellous bone graft, either vascularized or nonvascularized, is accepted as the ideal graft material. Most often it is taken from the iliac crest. But cancellous bone is sometimes not available in sufficient quantity, and harvesting of the bone imposes the potential complication, including pain, blood loss, infection, donor site contamination, and instability.

Biocompatible substitute materials like porous hydroxyapatite or tricalcium phosphate offers the surgeon yet another option, but as they contribute no significant structural support, they can only be used in areas with intrinsic skeletal stability and may require postoperative immobilization. Incomplete healing has been found more commonly in patients with large lesions. Such patients also need a longer observation period [3–5]. Although Persson and Wouters [15] have reported excellent results with bone cement filling, bone cements have no biological capacity and are less desirable in treating curable lesions in which the goal is complete restoration of anatomy and function. It has been questioned whether these artificial implants are really appropriate for such use. Curettage followed by bone cementing as a surgical treatment for giant cell tumor of bone is usually applied in the vicinity of a greater joint. The concept of curettage and subsequent bone cement has several advantages. It is simple and there is the possibility of immediate fixation. But bone cement has no biological loading capacity and remodeling power. It is hard to predict whether and for how long cemented bone can tolerate full weight-bearing without mechanical failure.

The use of frozen allografts was popularized during the 1970s. During the process of procuring grafts and providing them for reimplantation, multiple cultures are taken and donors are tested for infectious disease to prevent their transmission [7,8]. With careful screening as detailed by Buck et al. [16], the risk of human immunodeficiency virus (HIV) transmission has been estimated to be approximately one in 1.6 million. Deep-frozen (−70°C) allografts have the advantages of unlimited supply and no donor site morbidity. There is no increased operative time associated with its use. Other advantages of allografts are that it is a mechanical space maintainer and is immunologically inert. The use of allograft is an attractive option, especially in children or in aged people with osteoporosis and large benign lesions.

Although allografts undergo biological changes that are qualitatively similar to autografts, they are inferior to autografts in rate and completeness of healing for large benign lesions [17–20]. The loss of biological potential is often overcome by averting morbidity at the donor site and the need for sizes, shapes, or quantities of bone that often go beyond available autogenous sources. As a result, allogeneic cortical grafts are also used when bridging the segment after tumor removed to avoid the filling defects. This is done not only for osteogenesis but also for fixation [7,21]. Allograft may be used for a variety of orthopedic conditions and can achieve successful incorporation by surrounding tissue, revascularization, and replacement by new bone. Certainly, allograft cortical strut has an important role in the treatment of huge benign bone lesions after surgical curettage [17,22]. Allogeneic cortical strut with or without the addition of allogeneic cancellous bone, also appears to be an acceptable substitute for autogenous cancellous or vascularized bone and has previously been used as a graft for orthopedic surgery. This material has proved an effective substitute for autogenous bone graft in multicenter clinical usage [7,8,23].

Simple curettage usually leaves residual microscopic evidence of disease. Several authors have reported that using adjuvant treatment to eradicate these residual microscopic foci in association with extensive curettage of tumor leads to improved results. We used local adjuvant treatment with phenol and alcohol to further extend the margin. More recently, others have begun using methylmethacrylate dealing with the mechanical implications or consequences of creating a large defect [6,17].

This study demonstrates allogeneic cortical material provides the orthopedic surgeon and patient with additional choices in the repair of cavitary defects after tumor curettage. The procedures in this study are best for selected patients with a huge cavity lesion in a large long bone. The use of deep-frozen allograft bone avoids additional operative incisions and the surgical morbidity required to obtain autogenous bone graft. It is very difficult to compare the radiographic process of graft union due to the variants, including patient age, size and length of lesion, location of the defect, and the optional use of an internal fixation device. An allogeneic cortical strut can be used safely and successfully to graft cavitary lesions created after the complete removal of tumors. This method provides for healing of the graft and mechanical biomaterial support for temporary internal fixation, either in combination with cancellous bone or alone [22,24]. If needed, this type of allograft may be combined with an internal fixation device, because the strut graft could not be used completely instead of the rigid fixation.

The strut stent graft had the advantages of providing immediate stability and matrix for fixation. The internal fixation device was applied over the femoral lesions. The size, location, and radiographic appearance of the osseous defect dictated the method of fixation. When a lesion involved 50% of the cortical width, a reduction of normal bone strength of 50% or more in bone bending and torsion was assumed. Under these conditions, prophylactic fixation was considered, especially for weight bearing bones such as the femur. The rigid fixation shortened the rehabilitation period postoperatively and patients could return earlier to normal activities. The patients were allowed to exercise and ambulate with partial weight-bearing during the initial postoperative period with full weight-bearing after 6 weeks. The patients could usually return to normal activities after about 3 months.

The process of the incorporation of the allograft is slow due to a low-grade immune response or a lack of osteocytes in the graft or both. When large allografts are used, union to host bone can be achieved, but incorporation occurs slowly or not at all. An allograft can still function, as it provides structural support as well as scaffolding that may eventually be incorporated into live bone by the process of creeping substitution.

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